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Learner-Friendly Textbooks: Chemistry Texts Based on a Constructivist View of Learning

Uğur Taşdelen
Middle East Technical University
Turkey

Fitnat Köseoğlu
Gazi University
Turkey

In this study, the use of inquiry methods, learning cycles, a conceptual change model and analogy in creating alternative science texts was discussed. An alternative text on the topic of acids and bases was created by integrating the methods and models discussed in this paper. The alternative text and a sample of a traditional text taken from a textbook, which is still used in Turkish high schools, were given to two groups, totaling 42 pre-service teachers—the alternative text was given to an experimental group and the traditional text to a control group—in an experimental setting and their understandings of acids and bases were compared. In addition, in the second step of the study, the pre-service teachers read both texts and indicated their preferences in terms of interest, understandability and helpfullness.

Key words: science texts, conceptual change texts, inquiry, learning cycles, analogy

Traditional methods are mainly based on teachers and textbooks. Generally, alternative methods to traditional methods have been a reaction to the dependency to teacher and textbooks and suggest that students should learn directly by themselves, without so much direct influence from teacher and textbooks. Most of these methods share a constructivist view of learning. Constructivism claims that learners construct their own knowledge. Therefore, instructions should have been planned to connect knowledge with children's existing ideas and so too should materials (especially textbooks). The constructivist learner had a more important role in the learning process. From this perspective, the constructivist view of learning shifted the learning process from teacher- and textbook-centered to a student-centered model.

Teachers found a place in constructivist view of learning and took the role as a facilitator or coordinator. However, textbooks are still considered to conflict with the notion that children should acquire their own knowledge. Moreover, considering the fact that the students generally use their textbooks in class only, traditional textbooks are also a limited material for teachers who want to expand the learning process of children to daily life. Some studies showed the inadequacies of science textbooks for their numerous misconceptions, errors, and oversimplifications of science content and context (Abimbola & Baba, 1996), weakly designed activities (Anderson, Beck, & West, 1994) and their perpetuating mythical stories about heroic stereotypical scientists (Milne, 1998).

However, sometimes this was exaggerated. A radical method of pedagogy discontinued the use of science textbooks in the classroom and laboratories (Graesser, 2002). The aim was to get students to engage in the experiments

Uğur Taşdelen, Secondary Science and Mathematics Education, Faculty of Education, Middle East Technical University, Turkey; Fitnat Köseoğlu, Professor at Gazi University, Turkey.

Correspondence concerning this article should be addressed to Uğur Taşdelen, Gazi Üniversitesi, Gazi Eğitim Fakültesi, Kimya Eğitimi Anabilim Dalı, Teknikokullar, Ankara, Turkey. e-mail: e150647@metu.edu.tr

and find their answers and solutions, not to accept textual knowledge as the absolute truth.

The value of textbooks in education should not be underestimated considering the facts that the textbooks play a vital role in determining course curricula (Smith & Jacobs, 2003; Koseoglu et al., 2003), that students expected the textbook to be used as the source of nearly all information and as the framework from which all science was to be experienced and parents accepted the textbook as central and expressed concern if textbooks were not issued and used for assignments (Chian-Soong & Yager, 1993). Moreover, it should also be considered how texts play an important role in conveying implicit conceptions of science (Norris & Phillips, 2003), that textbooks that use effective teaching strategies improve student learning and provide good models for teaching (Bishop & Anderson, 1990) and texts, including textbooks, could play a central role in inquiry science curricula that are sensitive to students' learning about scientific practice (Hand et al., 2003). Moreover, a relatively few textbooks are used at a given level or area of science; these few represent the science studied for nearly all students (Chian-Soong & Yager, 1993).

On one hand, texts carry traditional features of teaching and may cause some misconceptions in science teaching, on the other hand, they are indispensable in science classes and curricula. Therefore, is there a solution to this dilemma? There is a need of "learner-friendly texts". In terms of a constructivist view of learning, learner-friendly texts are expected to (1) invoke students' existing knowledge, (2) connect current knowledge with previous knowledge, (3) enable them to replace misconceptions with scientifically excepted ideas (conceptual change), (4) explain abstract concepts with concrete examples (analogy), (5) replace scientific jargon with a narrative structure and (6) guide students to ask questions. These features can be extended; more features are beyond the scope of this study. In answer to the previous question; one of the answers to this question could be the use of alternative texts. A short review of the literature about alternative texts revealed that, during the past two decades, there have been some investigations into the effects of alternative texts on students' comprehension of science concepts and conceptual change. In these investigations, four different types of alternative text structures and alternative text-based strategies especially attracted our attention and our idea about the text in this study. Firstly, Musheno and Lawson (1999) applied learning cycles to science texts and compared learning cycle texts with traditional texts for students' comprehension. The learning cycle is a teaching methodology based on Piaget's model of intellectual development (Karplus & Their, 1967). It has mainly three phases: *exploration, term introduction* and *concept application* (Lawson, 1988; Renner & Marek, 1990). Musheno and Lawson (1999) created a learning cycle text in "pattern first—terms second format" contrary to traditional "terms-first" format. They found that science texts presented in the learning cycle format was more comprehensible for readers at all reasoning levels.

Secondly, examples of the use of texts in support of firsthand scientific inquiry instruction in the early elementary grades can be found (Palincsar & Magnusson, 2000; Ford, 1999). In their study, Palincsar and Magnusson (2000) developed a new text genre modeled on a scientist's notebook. This type of text modeled the use of scientific reasoning for the children, in contrast to the traditional texts that just presented a body of information. Palincsar and Magnusson compared notebook texts to traditional expository texts on the same topic and found that the notebook genre produced significantly higher results.

Thirdly, conceptual change texts and refutational texts were commonly used by researchers to change alternative concepts that students might have. These texts are based on the conceptual change model proposed by Posner, Strike, Hewson, and Gertzog, W. A. (1982). Both texts aim to contrast a scientific concept with misconceptions. The difference is that in the conceptual text, before giving the information that shows the inconsistency, students are asked to make predictions about the situation. Research into the conceptual change text (Roth, 1985; Wang & Andre, 1991; Chambers & Andre, 1997) and into refutational texts (Hynd & Alverman, 1986; Guzzetti, Williams, Skeels, & Wu, 1997; Palmer, 2003) showed that these texts were effective in changing student's alternative conceptions. A meta-analysis of 25 studies into refutational texts (together with another 35 related investigations from science education) determined average effects ranging from 0.50 to 1.77 for each instructional strategy and examined students' long-term conceptual change (Guzzetti, Snyder, Glass, & Gamas, 1993). Results showed that ordinary forms of text were ineffective in producing either short- or long-term conceptual change.

A fourth type of alternative text is the analogy-enhanced text. Analogy is a powerful tool used in constructivist views of learning because it can construct a relation between prior knowledge and new knowledge. Studies into analogy texts done by Glynn and Takahashi (1998) and by Paris and Glynn (2004) showed that the analogy enhanced text had a positive effect on students' science knowledge.

The purpose of the study is to investigate the effect of the use of an alternative science text created through the integration of some methods based on a constructivist view of learning in a quasi-experimental setting and to get some feedback from chemistry teacher candidates about the use of this text as a textbook in class. Accordingly the research questions were: (1) Is there a difference between the alternative text and the traditional text in terms of pre-service teachers' understanding of acids and basis? (2) What are the preferences (whether the alternative text or the traditional text) of the pre-service teachers regarding the text and their reasons for that preference? The traditional text (also called the control text in this study) can be defined as the passage taken from a commonly used chemistry textbook which has a definition first-example later format, has an expository genre, and doesn't have any refutational elements or analogies. The alternative text has been described in the methodology section and given in Appendix. The content coverage and a more detailed description can be found in the methodology section.

Method

Population and Sample

The target population of this study was pre-service chemistry teachers in Turkey; however, the accessible population consisted of all the chemistry teacher candidates at Gazi University in Ankara. We selected teacher candidates because they were both students and teachers. In our testing of their understanding of acids and bases they could be considered students because of their limited conceptual understandings of scientific concepts (Huinker & Madison, 1997). In obtaining feedback about the experimental text they can be considered as teachers.

There were two groups of chemistry teacher candidates in the university. The first group consisted of 40 students enrolled in the Secondary Science and Mathematics Education Department and the other group consisted of 40 students enrolled in a non-thesis master degree in chemistry education. Both groups had had the same education courses and chemistry education courses, however, the main difference was that the non-thesis master degree students graduated from the chemistry (not chemistry teaching) department or chemical engineering department and attended the non-thesis master degree program to teach chemistry in high schools—just like those on a teaching certificate program. It was compulsory for them; otherwise they were not allowed to teach chemistry.

In this study, not all subjects were available, therefore a convenience sampling was used. Forty-two chemistry teacher candidates were selected which were 52.5% of the total subjects. Twenty-one students were senior chemistry teaching students in the Secondary Science and Mathematics Education Department and the other 21 students were non-thesis master degree students in chemistry teaching. Because of these different backgrounds, students in each group were randomly assigned to either the experimental group or the control group separately. The experimental group consisted of 20 students (9 Chemistry Teaching major students and 11 non-thesis master degree students) and the control group consisted of 22 students (12 Chemistry Teaching major students and 10 non-thesis master degree students). All of the students were taking the course of "Analysis of Science and Chemistry Textbooks" and the text activity of the study was applied as a part of the course.

Instruments

The experimental text and the control text. The idea was to integrate the four structures and strategies mentioned above in one text body and to create an alternative text for chemistry teachers in a manner supporting a constructivist view of learning. This text would have all the features (and advantages) of the alternative texts mentioned previously and also be able to serve as an alternative material for teachers. For our study, the concepts of acids and bases were selected as the topic of the text. The content coverage was taken from the 10th grade chemistry curriculum of the Ministry of National Education of Turkey. The text covered

the first section of the unit *Acids and Bases*, namely, the introduction and definitions of acids and bases. This alternative text was used as the experimental text in the study.

The first major difference of the experimental text from the control text was that it was written in an investigative fashion and designed to help students and teachers use in an inquiry-based science classroom. Inspired by the scientist's notebook genre of Palincsar and Magnusson (2000), the genre of our text has been modeled on a student's diary. In the text, a student told of his adventures and those of his friends in learning science through inquiry. In their adventures they acted like real scientists: They were curious about the things around them, they investigated, they asked questions, and they proposed ways of finding answers (e.g. in the text, they designed an activity to identify the substances as acidic or bases and tabulated their results), etc. In other words, they showed all the necessary inquiry skills that we hope the students in our classes acquire. Since the genre of the text was modeled on a student's diary, the story was told from the student's point of view; *I* and *we* were used instead of *he/she* and *they*. This format was thought to be more motivating for the students who read this text since they would put themselves in the place of the student(s) in the text.

Another point in which the experimental text differed from the control text was the use of the learning cycle format; "pattern first—terms second format" as described by Musheno and Lawson (1999). At the beginning of the text, the main character of the text explained how he searched for some samples of acidic and basic substances that one could find at home. Every student has had daily life experiences with acidic and basic substances more or less. Giving examples of acidic and basic substances was thought to enable the readers to recall their preexisting knowledge. Throughout the text, the characters of the text had more experiences with acidic and basic substances and obtained clues about how to identify acidic and basic substances. At the end of the text, students connected the clues and built the definitions of acids and bases (which are actually scientific definitions which can be found in any chemistry book) and since the readers would have some idea about acids and bases at that point, they could build their own knowledge easier.

To target a common misconception that is "substances that contain H are acidic and substances that contain OH are basic", a part in the story was organized to serve as refutational text. This part was slightly problematic because, normally, refutational texts were usually so. Since a long refutational section could inflate the size of our text, the refutational part was kept as concise as possible. In the refutational section, one of the characters held the misconception and exposed it. Another character explained that this idea was wrong and showed another idea (the scientific one) which was more plausible and fruitful.

Finally, in order to enhance the students' interest, the soccer analogy was used to help explain the definition by Brønsted and Lowry. In this analogy, the striker was presented as the proton donor, the goalkeeper as the proton acceptor and the ball as the proton.

The control text was adapted from a chemistry textbook, which was widely-used in Turkish high schools. The coverage was the same as the experimental text, namely the introduction and definition of acids and bases. Only the text part was taken, no illustrations and sample problems were included to control text.

Tests. Students' understanding was measured with the Acids-Bases Achievement Test. This test was developed by the researchers. It had a total of 9 items; 5 essays and 4 short answer items. There were 5 items measuring knowledge and retention (example; what is the definition of acids and bases according to Arrhenius?) and 4 items measuring comprehension and inference (example; which of the below is/are false?). Each item was scored out of ten points. A scoring rubric was designed and two independent raters scored the test. Interrater reliability was calculated for retention and inference items separately. Interrater reliabilities were found; for pretest $r_{xy} = .94$ and $r_{xy} = .98$ for retention and inference items, respectively, and for posttest $r_{xy} = .87$ and $r_{xy} = .98$ for retention and inference items, respectively.

To measure the students' reading comprehension ability, the Reading Comprehension Test was administered to both groups. Since reading comprehension ability was an important variable in this study, this test was used to see whether this variable was the same for both the experimental and control group. If it was not the same, reading comprehension would be used as a covariate. This test was developed by Coskun (2002) and consisted of a

scientific article taken from the journal *Discover* and of 12 items; one short answer item, 7 multiple-choice items and 4 true-false items. Cronbach's Alpha was calculated as .80.

To obtain feedback on the alternative text, a text measure was administered. The text measure was a quantitative and qualitative measurement tool consisting of three items. These three items asked the students to rank the text in terms of being (a) interesting, (b) understandable for students and (c) helpful for teaching and, then, asked them to write their reason(s).

Procedure

The data collection procedure had two steps. In the first step (the step of achievement testing), a Pretest-Posttest Control Group design was used. The experimental text was given to one group; this group was called the experimental group and the control text was given to other group; this group was called the control group. Both groups read the texts in 30 minutes, none of them asked for extra time. The Acids-Bases Achievement Test was administered as Pretest and Posttest. The Reading Comprehension test was administered before treatment.

In the second step (that of teacher comments), after completing the first step, students were given one sample of the experimental text and one sample of the control text and asked to read the texts as a teacher. All students read both texts during a given period of time. Then, they were asked to rank the texts by answering three items and writing their reason(s): (a) Which text, do you think, your students would find more interesting? (b) Which text, do you think, your students would find more understandable? (c) Which text, do you think, would be more helpful for your teaching?

Analysis and Results

As the data collection procedure consisted of two stages, the data collected in each stage was analyzed separately. The data collected in the achievement testing stage were analyzed with descriptive and inferential statistics whereas the data collected during the teacher comments stage were analyzed with descriptive statistics only.

The descriptive statistics related to scores on the Acids-Bases Achievement Test was given in Table 1 and Table 2. The pretest scores for knowledge items of the experimental group are higher than those of the control group; however, the posttest scores of the control group are higher than those of the experimental group. The gain scores are 11.6 for the

Table 1
Descriptive Statistics of Knowledge Scores of Acids-Based Achievement Test

	Group	*N*	Mean	*SD*
Pretest	Experimental	20	28.025	9.666
	Control	22	25.182	10.996
Posttest	Experimental	20	39.650	5.140
	Control	22	44.341	4.671

Table 2
Descriptive Statistics of Comprehension Scores of Acids-Based Achievement Test

	Group	*N*	Mean	*SD*
Pretest	Experimental	20	24.475	7.728
	Control	22	21.477	11.483
Posttest	Experimental	20	28.600	6.299
	Control	22	26.159	10.370

experimental group and 19.2 for the control group. These scores show that the control group, when answering the knowledge items, showed a greater improvement than the experimental group did. On the other hand, the pretest and posttest scores show that there is no obvious superiority of one group over another in terms of the scores on the comprehension items. The gain scores for the experimental and control groups are very close, 4.1 and 4.7, respectively.

As an inferential statistics method, ANCOVA was used in this study. The significance level (α) was set to .05, as this value is most common in educational studies. Pretest scores of the Acids-Bases Achievement Test and the scores of the Reading Comprehension Test were used as covariates. The purpose of using ANCOVA in this study was to investigate the difference between the knowledge and understanding of students who read the experimental text and those who read the control text when their preexisting knowledge about acids and bases, and their reading comprehension ability were statistically controlled. The result of the analysis shows that there is no significant difference in students' knowledge scores ($p = .055$, $p > \alpha$) nor in their comprehension scores ($p = .641$, $p > \alpha$).

In the teacher comments stage, the data collection procedure was analyzed with descriptive statistics only because no generalization was needed in this step. The analysis of the rankings shows that the students in our study overwhelmingly favor the experimental text over the control text. The results as a bar graph are given in Figure 1. The reasons why they preferred the alternative text are summarized in Table 3. This result was expected prior to the study and supports our idea of creating an alternative text. However, their reflections are more important for our study as they will provide valuable feedback for future studies.

Conclusion and Discussion

The literature cited in this paper indicated that alternative texts did have some effect on students' understanding. However, the text we have created did not show any remarkable effect on students. The mean of the control group's knowledge scores was improved (the difference between pretest and posttest scores) more than those of the experimental group's knowledge scores but ANCOVA results showed that this was not statistically significant. The means of both groups' comprehension scores were almost equally improved; no statistical significance was observed as a result. While selecting the sample, we assumed that pre-service teachers could be considered as students because of their limited conceptual

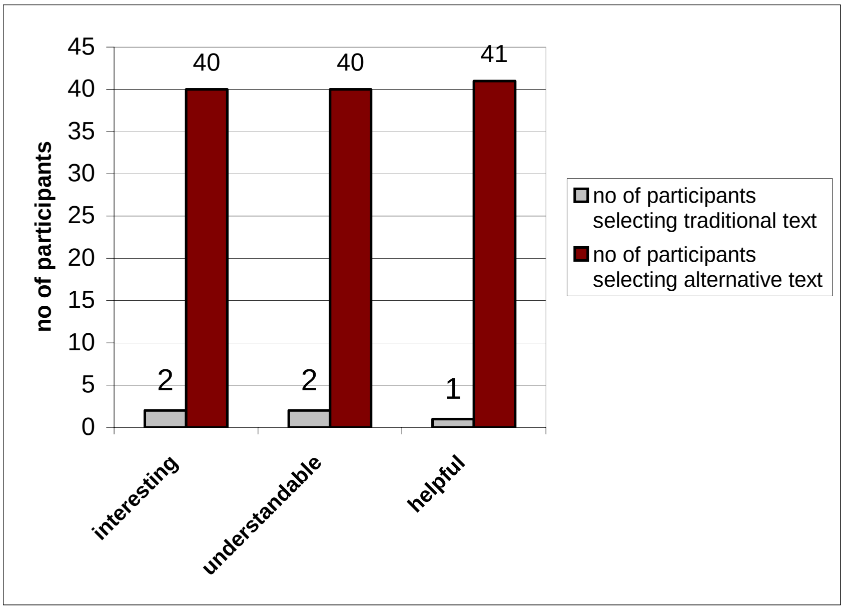

Figure 1. Graph of students' rankings for interestingness, understandability and helpfulness of the alternative text

Table 3
Summary of Preservice Teachers' Reasons for Selecting Alternative Text

Interesting because;
- It gives examples of acids and bases from daily life.
- It gave examples from daily life. It asked interesting questions. The activities could attract students' attention.
- Tables and figures make the subject more visual.
- It is more interesting; it has experiment (activity) section.
- First it makes students curious, then gives examples from daily life experiences and explain them with scientific definitions and then it creates desire to perform experiences.
- Its narrative feature is very interesting and fascinating, it is not boring.
- The words are not clichéd, they are designed to attract curiosity and the text has a nice beginning
- There are not too many scientific terms. It is not confusing one's mind by giving too many terms.
- It not only gives knowledge but also makes daily knowledge more fruitful.
- Students acquire their own knowledge through investigation. Students learn themselves.

Understandable because;
- The examples of acids and bases are very common and well known
- I have easily imagined the concepts in my mind. There is no concept introduction alone. The concepts were accompanied by examples.
- It is more understandable since it doesn't use textbook language.
- The students in the text questioning scientific data. They learn the first simple knowledge then go through more sophisticated one. They also deal with alternative conceptions.
- They explain step by step how they learn and how they investigate.
- By reading this text, students find themselves making those investigations in the text and this makes them benefit from the text more.
- The text focuses on the points where students can get confused.
- Students can learn just like in peer study.
- Its narrative future can make the concepts more understandable but the text is too long it can be boring for students.

Helpful for teachers because;
- The figures could be useful for teachers to explain the acid-base concepts.
- The examples are useful in introduction the acid-base concepts.
- The teacher in this text is a facilitator or a guide.
- The text is suitable for students' level.
- I think if we let the students learn just like in the text, the concepts in chemistry can be more amusing.
- The text makes the students be curious and shows them how to investigate.

understandings of scientific concepts (Huinker & Madison, 1997) but this assumption could have failed and maybe, therefore, no difference was observed. Another possibility is that the testing threat could have affected the results since the period between pretest and posttest was relatively short (two hours).

One of the subjects in the experimental group failed to finish the tests. No missing data treatment procedure was implemented since the loss of the subject constituted 5% of the group and this percentage was not a serious threat to the results. To minimize the implementation threat, both experimental and control texts were kept equally long. No pictures, questions, etc., other than the passages and the tables, were included in the texts. Since the sample was not randomly selected, the characteristics of the subjects were a threat to the study. In this study, reading comprehension ability was most likely to affect the results of the results of the study. To minimize this threat, the Reading Comprehension Ability Test was implemented and the scores obtained from this test were used as a covariate to adjust the means obtained from the Acids-Bases Achievement Test. There were no other threats observed.

Although no significant difference was found between both groups in terms of their Acids-Bases Achievement Test scores, the second step of the procedure, in which subjects prefer one text over another and explain why, gave some valuable feedback and showed that our experimental text has promise. The subjects in this study were not told about which text was the alternative nor were they told about what type of structures or strategies in the alternative text were used. As we examine the reasons why the teacher candidates in our study found our text interesting, however, it can be clearly seen from their reflections (Table 3) that they address these structures and strategies. For example they address the learning cycle format by the statements like “It (the alternative text) gives examples from daily life”, “First it makes students curious, then gives examples from daily life experiences and explain them with scientific definitions”, “The words are not clichéd, they are designed to attract curiosity and the text has a nice beginning.” It seems that they liked the student’s diary model due to its narrative feature. Some of them thought that the alternative text was more interesting and understandable because it used “daily language”, not “textbook language”. On the other hand, two students who preferred the traditional text stated that they found it (the traditional text) more interesting and understandable because it was more concise, it didn’t distract students with long stories. Actually, they pointed out something that we avoided while creating our alternative text. We tried to make our text as concise as possible because we didn’t want the main content to be lost in the story. However, in any case, our alternative text would be longer than the traditional one due to its structure and content, we could not make our text shorter than this form allowed.

The teacher candidates also noticed the inquiry feature of the student’s diary model. They stated that “The students, in questioning scientific data…”, “explain step by step how they learn and how they investigate.” and “Students acquire their own knowledge through investigation …” etc. They thought the text was more interesting and understandable because “By reading this text, students find themselves making those investigations in the text and this makes them benefit from the text more”.

Only one student noticed the refutational text feature. The reason is most likely that the refutational text is embedded in the main text. In a traditional way, the refutational text can be put where students can notice it at first glance like in colored textboxes or in on a separate page. In our text, however, the refutational text is part of the narrative feature (the story) and it is thought to serve in that way. For example, there is a point of dissatisfaction for the students in the story whereby ammonia doesn’t fit the children’s definition of “Substances that contain H are acidic and substances that contain OH are basic.” The “being intelligible, plausible and fruitful” phases are accomplished by explaining this by means of Brønsted and Lowry acid-base definition.

The teacher candidates also liked the analogies used in the text. Texts with analogy not only allowed the students to understand the concepts but they also supply teachers with analogies that they can use in the class.

The major drawback of this study is it’s limited generalizability. We can generalize this study only to our accessible population. To increase the external validity and to make the extension of generalizability available for other researchers, the procedure of this study was described as clearly as possible.

Implementation

This text format is a challenge to traditional formats and may not be the perfect one but with its narrative feature and different structure, it contains promise in being able to replace traditional textbook formats. For further improvement in creating better texts, these suggestions are worth considering:

1. The number of studies into alternative text formats is already very limited. More studies are needed. The feedback obtained from teachers in this study are encouraging for the conducting of further studies.
2. This study is limited to a certain number of pre-service teachers. More teacher opinions could give more valuable feedback.
3. The format of the text can be improved. For example, more interesting stories can be created or better analogies can be found. Moreover, other strategies such as concept maps, POE (predict-observe-explain) and 5E can be integrated into the text body to obtain better texts.

4. The effects of the text as supporting material in constructivist classes needs to be investigated. This text could be good material for the teachers who oppose the use of traditional texts in their classes.
5. The most important barrier that alternative texts encounter can be students' habits of learning; they are used to direct reception of knowledge from textbooks. It may take time for students to benefit more fully from alternative texts.
6. The effect of the text should be investigated at the primary school level (with primary school students) and compared with the results here. Guzzetti, Williams, Skeels, and Wu (1997) state that the inclusion of narrative structures is unnecessary at the secondary level and accordingly, as our text format has narrative features, there is a possibility that the higher the students' level, the weaker the effect of the text.
7. This alternative text was a model text for the recent primary education curriculum reform in Turkey. Many countries had similar curricular reforms and will need alternative materials. This text format or an improved one could be a good alternative.

Our findings suggest that the concepts of acids and bases can readily be taught by teachers using this alternative text in the classroom or laboratory. This text was not intended, however, to be primary source of learning; it cannot replace hands-on activities, inquiry activities and the teacher's role in the classroom or laboratory. As Musheno and Lawson (1999) stated "the textbook readings of concepts still must be used only after the concepts were already experienced."

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Appendix

Alternative Text Used in Experimental Group

ACIDS AND BASES

Things We Discovered about Acids and Bases

Our teacher told us that this week we were going to study the concepts of acids and bases. We made cooperation. My friends Deniz and Burak went to library for collecting information about acids and bases. Ayla and me had the job of collecting anything that could be acidic or basic. I knew that lemon juice and cola are acidic. Both of these tasted sour so I concluded that other acidic things would taste sour. I opened refrigerator and took out thing I suspected of being acidic: an apple, an orange, a tomato, a bottle of soda. It was more difficult to find things that were basic. I search through the rooms. I found soap in bathroom. I knew soap was basic. I tasted the soap; it was bitter. I found baking powder in the kitchen, which was also bitter. I thought that ammonia and bleach could be basic too because my mom used them for cleaning purposes like soap.

The day we had our chemistry class we gathered in the classroom. Like me, Ayla brought some substances, which she thought to be acidic or basic: vinegar, milk, milk of magnesia. Well, we needed to find out a method to identify these substances as acidic or basic. We could identify some substances as acidic or basic by tasting them. However, this was not a convenient method because some substances could be harmful as well as tasting was not an objective method. We had to act like scientist and use a more scientific method.

Burak surprised us by showing us a purple liquid, which, he said, was a magical liquid used to identify acidic or basic substances. “It just turns pink in acidic solutions and turns green in basic solutions”, he added. Well, that would be an interesting experience.

We prepared solutions of the items we brought in different glasses and obtained the observation/result table below:

Item name	Observation (color)	Result
Soda	pink	acidic
Lemonade	pink	acidic
Ammonia	green	basic
Backing powder	green	basic
Soap	green	basic
Orange juice	pink	acidic
Tomato juice	pink	acidic
bleach	green	basic
Milk of magnesia	green	basic
Vinegar	pink	acidic
Water	purple	unidentified

Now that we found out which one was acidic and which one was basic we needed how the scientists defined acids and bases. We read the books that Burak and Deniz found in library. First definition was proposed by S. Arrhenius. He said; “an acid is a substance which releases H^+ ions in water and a base is a substance which releases OH^- ions in water.” We investigated ionization of some acids and bases:

$HCl_{(aq)} \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$

$NaOH_{(aq)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$

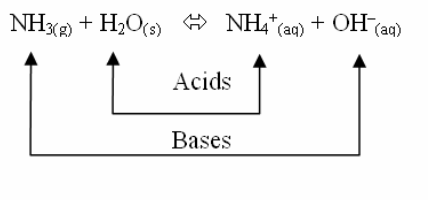
These examples were in accordance with Arrhenius' definition. Ayla said, "So, it means that substances that contain H are acidic and substances that contain OH are basic." But when we look at our own table we were confused. Ammonia was basic in our table but the formula of ammonia was NH_3; it contained H, no OH! On the other hand, acetic acid , which was found in vinegar contained OH. Ayla said, "Arrhenius' definition is wrong!" "Not wrong, just inadequate!" Burak added. We were all agreed that we needed a better definition. "There is another definition here," said Deniz by showing us a book. We learned from the book that, after Arrhenius, two scientists named Brønsted and Lowry defined acids and bases like this; "In aquous solutions, acids are proton donors and bases are proton acceptors." "Like in a soccer game," said Burak, "The striker shoots the ball and the goalkeeper catches the ball. If the ball is the proton then the striker is the acid and the goalkeeper is the base". We laughed out.

We wrote the ionization equation of ammonia in water.

$NH_{3(g)} + H_2O_{(s)} \Leftrightarrow NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$

According to the definition of Brønsted and Lowry, ammonia was base because it accepted a proton. "I think water donates the proton here. So, water must be acid here." said Ayla. She was right. Water lost H^+ in this equation and ammonia accepted that proton.

"Why don't we reverse this equation and look at it?" asked Deniz. "What do you mean?" I asked. Deniz explained, "From the bi-directional arrow I understand that there is a chemical equilibrium here. In forward reaction, H_2O releases a proton so it is an acid. In reverse reaction, NH_4^+ releases a proton so it is an acid, too. In other words, we have two acids. In the same way, NH_3 and OH^- were bases." We marked relevant substances on the reaction as acids and bases and obtained this:



"This acids and bases are called as conjugate acid-base pairs", said Ayla showing a chemistry book's page. "But, I am completely confused about this definitions," she added. Burak responded, "Any Arrhenius acid is also a Brønsted-Lowry acid, and any Arrhenius base is also a Brønsted-Lowry base.

We made a table about acid-base definitions to review what we had learned:

	Arrhenius	Brønsted-Lowry
Acids	form hydrogen ion	donate hydrogen ion
Bases	form hydroxide ion	accept hydroxide ion
Sample reaction(s)	Acid: $HCl_{(aq)} \rightarrow H^+{}_{(aq)} + Cl^-{}_{(aq)}$ Base: $NaOH_{(aq)} \rightarrow Na^+{}_{(aq)} + OH^-{}_{(aq)}$	$NH_{3(g)} + H_2O_{(s)} \Leftrightarrow NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$
Specification	Hydrogen ion is the source of the acidic character and hydroxide ion is the source of the basic character. Not suitable definition for some acids and bases like NH_3, CO_2	Compromise Arrhenius acids and bases. Based on proton exchange

I decided to identify more acidic and basic substances at home. I request the magical liquid from Burak. He told me that it was just red cabbage juice! All I had to do was to cut cabbage into small pieces and boil and filter the liquid.